ENGITECTURAL DESIGN

DEBORAH RUTH GAGLIARDI, AIA, EIT, CSI
ARCHITECT, INTERIOR DESIGNER, ENGINEER IN TRAINING
CARTER & BURGESS
FORT WORTH, TEXAS

Abstract

Traditionally, Architecture and Engineering have been disciplines practiced exclusive of one another's input and collaboration. This seemingly awkward custom is due in part to tradition and to the two distinct perspectives each discipline has concerning the function of a building and it's many components. In the past, collaboration on a project generally occurred out of necessity, and can usually be attributed to a system and design integration problems. In most instances, these issues are related to the mechanical systems of building, and in a hot and humid climate the issues are magnified. Therefore, this paper will discuss the concepts and merits of a new design process called: ***Engitectural Design***.

Engitectural Design is the concept of blending the many design and aesthetic concerns of architecture with the more technical aspects of engineering, especially in the area of mechanical HVAC systems. The use of this new design procedure will reduce, if not eliminate, current problems with clearances, mechanical room size and optimal area selection. Merely incorporating the mechanical needs of a building during the schematic phase will reduce communication problems that cause the above mentioned problems, and thus optimize the system. This paper will address the mutual concerns of both professions as it pertains to materials, lighting, surface finishes, passive and active solar and the use of landscaping, focusing on the benefits of mutual agreement in a hot and humid climate.

To be successful, the collaboration must begin in pre-design and continue through project completion. During initial implementation of Engitectural Design, a firm can expect each phase of a project to take longer than usual. Lack of established relationships, poor communication and professional territorial rights will exist in the beginning. However, over time a firm can expect a time reduction due to fewer revisions and the elimination of duplicated work.

As it pertains to today's more advanced HVAC systems, this new cooperation and understanding of the needs within disciplines will yield a more effective and efficient operating unit for today's hot and humid environment.

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Hot and Humid Climates

In today's competitive business climate the Architectural/Engineering firm's primary goal should be to produce the most efficient, functional and aesthetic building design, while creating a profit and the desire for repeat business. Engitectural Design advocates combining the efforts and talents of both the Architect and Engineer to accomplish this goal.

Designing a climate control system in a hot and humid climate requires special attention from both disciplines. To balance the needs of the owner and mother nature it is essential to begin the design phase addressing the climate control system requirements.

The majority of the heat gain through the building envelope and ventilation (infiltration) in a hot and humid climate is due to external sources, followed by the internal sources such as lighting, equipment, and people. The affects of the building design on the total heat gain or cooling load demands trickle down and are felt in the mechanical system design. Engitectural Design, and this paper, focus on combining the expertise and knowledge of each discipline to benefit the overall design of a building system as a whole.

The potential benefits of Engitectural Design and the overall system design impact in a hot and humid climate shall be examined by identifying, analyzing, and then better understanding the impact of the individual cooling load parameters.

The primary parameters to calculate a building design cooling load in a hot and humid climate are:

- Project location
  - City and State
  - Latitude
  - Elevation
  - Site landscaping
- Number of stories
- Use of conditioned space
  - Conditioned floor area
  - Floor to ceiling heights
  - Floor to floor height
  - Wall area and orientation
  - Roof and basement area
- Construction materials
  - Walls
  - Roofs
- Exterior surface color
  - Walls
  - Roof
- Fenestration
  - Area and orientation
  - Construction material
  - Shading
- Lighting
  - Wattage
  - Scheduled time of use
- Occupants
  - Number
  - Activity level
  - Scheduled building use
- Environmental conditions
  - Required ventilation
  - Indoor dry-bulb temperature and relative humidity as selected
  - Outdoor temperature and humidity at a selected design condition

Nine separate design area parameters are listed above, all of which must be considered in the design of the climate control system. Yet, the mechanical engineer is left out of at least eight of the essential design areas during the critical design phase. Excluding the mechanical engineer's vital input from the building schematic design phase, actually forces the engineer into designing a retrofitted climate control system.

Retrofitting the mechanical system to a building design is equivalent to adding the air conditioner to a car after it leaves the factory. The nonfactory car air conditioner will work, but the owner will pay more, and experience clearance and tolerance obstacles. Automotive engineers do not force fit the air conditioning system into the car, but integrate the overall design of the automobile and the air conditioner.

Similarly, custom fitting the mechanical system to a building can help reduce cost, and eliminate clearance and other coordination problems often associated with retrofitting. This is the primary focus behind Engitectural Design, reducing problems and cost, avoiding discomfort to all involved.

Human Thermal Comfort

It is often stated an occupant will remember two things about a building; did the roof leak and the interior temperature. For the most part, these two basic human comfort items are taken for granted, until they do not function properly. Human beings are considered constant-temperature creatures, and due in part to the commercialization of the refrigeration cooling system in the early 1950's, have become accustomed to having their thermal surroundings constant all year round.

Engitectural design is conducive to thermal comfort system design. The human thermal comfort level is a complex combination of both perceived and actual environmental factors that include illumination, acoustics, sanitation, and thermal control .

Thermal control, and the interaction with ones' immediate surroundings can be broken down further into temperature, drafts, humidity, air movement and sounds created by the equipment used to control the thermal environment. These stated factors are also the primary areas of concern for a mechanical engineer when designing a climate control system in a hot and humid environment. Elimination of the engineer in the design phase of a building limits the engineer's ability to maintain quality control of the mechanical system.

Mechanical systems can account for up to fifty percent (50%) of construction cost. The man-hour cost of including the engineer in the design phase of the building can be more than offset by the savings of Engitectural design implementation. Working together can reduce the costs of design man-hours, the equipment, installation, maintenance, and energy consumption.

Sol-air

Sol-air is defined as "the equivalent outside temperature that would, in the absence of solar radiation, cause the same amount of heat gain as actually exists due to both the real outside air temperature and the solar radiation" **(1).** In laymen's terms the sol-air temperature is an imaginary higher temperature, that takes into account the effects of the solar heat absorbed by the opaque wall and roof surfaces.

In the hot and humid climate the imaginary, higher sol-air temperature must be taken into consideration when calculating and designing a climate control system. The higher sol-air temperature is substituted for the summer design temperature. Coordination in the design phase can help reduce the affects of the sol-air temperature.

Building materials and color, site orientation, and strategically placed landscaping are just a few of the factors that can be utilized to manipulate the sol-air temperature. Manipulation of the aforementioned items can be done with little or no increase in the building cost, but can reduce the total energy expense. Engitectural Design seeks to take advantage of these design areas to the benefit of the owner, Architect and Engineer. Everyone loves a well design system.

Unconditioned Adjacent Temperatures

Sol-air calculations provide a means for evaluating an effective outdoor temperature for building shells exposed to solar radiation. Interior spaces can also effect the final design cooling load figure. Unconditioned adjacent spaces that, border the conditioned space, must be taken into consideration when designing a climate control system.

An overlooked, but critical element included in the unconditioned adjacent temperature effect is a building crawl space. The added concern of the crawl space in a hot and humid climate is moisture. Venting the crawl space raises the temperature to that of the exterior, thus heating the floor. Failure to vent a crawl space creates an accumulation of condensation. Condensation and high humidity produces a potentially damaging combination, to both the structure and energy consumption.

Insulating the floor and venting the crawl space can aid in lower the unconditioned adjacent temperature effects, but the addition of heat below the floor is desired in the heating season, therefore closeable vents should be utilized to adjust for the seasonal climate needs of the building.

The unconditioned adjacent temperature effects experienced in the unconditioned and unvented vacant spaces can produce higher temperatures than the actual outdoor temperature. The climate control system design would, by professional practice, treat the adjacent unconditioned space as an interior element, which could result in a dramatically undersized system. This situation often exists in office buildings that remain partially vacant for an extended period of time.

This special case of the consequences of unconditioned adjacent temperature is an excellent example of the importance of Engitectural design. Working together the Architect and Engineers can integrate ideas into the building design to help minimize the affects of both sol-air and unconditioned adjacent temperature.

Building Materials

When dealing with a hot and humid climate selecting the proper building materials, with regard to the climate, is paramount. The concern of most Architects, in this area, will be the fear of limited selection. This need not be the case. Additionally, proper selection of material to the climate will help ensure both proper aging and weathering of the building.

Humid areas create excess moisture and condensation which can play havoc on building materials, as well as create structural problems. Wood is required for many structural applications, and desired in many aesthetic situations, but proper selection for moisture control is vital.

Wood products selected for use in humid areas should be based on their Coefficients for dimensional changes due to shrinkage or swelling **(2).**
The recommended moisture content value (at time of installation) is eleven percent (11%). Figure A.1 represents the maximum amount of relative humidity required to avoid visible condensation.

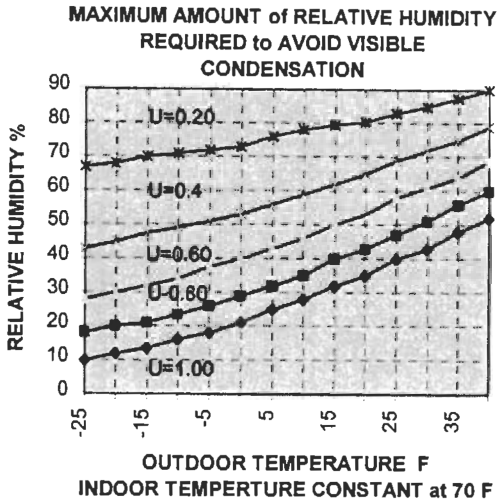


Figure A.1

Failure to control the condensation, visible or otherwise can result in the following negative and corrosive effects on the building material:

1. Dimensional changes when the moisture content changes. This is most common with wood, and would also include plant and animal fibers. Brick can show negligible dimension changes.
2. Moisture is the essential factor in chemical changes (i.e., rusting), physical changes (i.e., spalling of masonry) and biological changes (i.e., wood rot). Surface condensation can not only destroy aesthetic surfaces but often includes potentially dangerous damage to structural members.
3. Water is an excellent conductor of heat, thus it increases the thermal conductivity for heat flow.

Hot humid climates are best suited to utilize brick as a building material. The thermal conductivity of brick offers the benefit of releasing heat accumulated and stored in the brick material during the day can be released and used in the cooler evenings to reduce heating needs.

Fenestration

Fenestration can be both positive and negative in a hot and humid climate. The Architect understands the importance of the ambiance of the building. Fenestration determines not only the view of the outside world from the occupants perspective, but is equally important in how the outside world views the building.

The Engineer is forced to calculate the sensible heat gain (up to 200 BTU/SF), created by the window. The solution to fenestration in a hot and humid climate is location, shading, and reflectance. When calculating heat flow through fenestration two sources of heat flow must be considered: transmission, also know as conduction heat gain, and solar heat gain **(3).** Transmission is created by a difference between outdoor and indoor air temperatures, and is not limited to fenestration. Solar heat is present only during the day when the fenestration is exposed to solar radiation, and is directly proportional to the intensity of the radiation and angle of incidence.

The total load considered through fenestration is therefore a combination of both the transmissions + solar heat gains. The simple act of shading the glass can reduce a southern facing window to the equivalent of a northern window. Figure A.2 represents the solar reflection, transmission and absorption at fenestration **(4).**

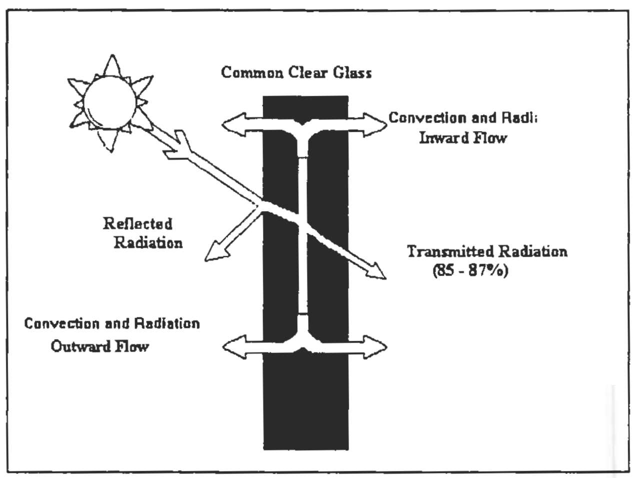


Figure A.2

This illustration clearly reflects the need to properly protect fenestration from solar heat gain, yet maintaining the aesthetics vital to any building. Proper coordination with all disciplines can resolve the balance of fenestration required between natural lighting, natural ventilation, heat transfer and aesthetics.

Lighting

Lighting remains a pivotal point in Engitectural design. Lighting is the one element that demands the attention and integration of all disciplines. The combination of needs and desires of the architectural, mechanical, electrical, structural, and even landscape designs can dramatically affect the building aesthetics, function, security, and final budget.

The importance of the lighting system to a building design is best reflected in the Energy Policy Act of 1992, also known as EPACT '92. The Executive Order 12759, Federal Relighting Initiative aims by the year 2000 reduce overall energy use (Btu/ft^2) from 1985 energy use levels, to the extent these measures minimize life cycle costs and are cost effective **(5)**.

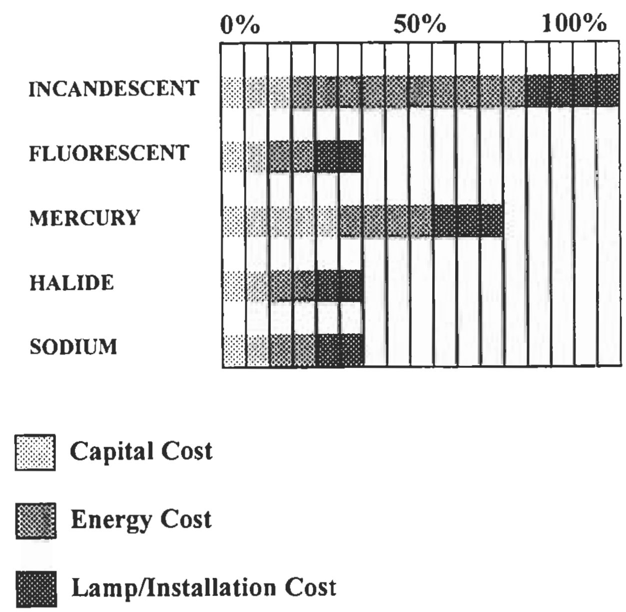
Commercial buildings lighting electricity consumption can be as high as fifty percent (50%), including the HVAC effects. One of the primary areas EPACT '92 influences is the use of natural lighting combined with the elimination of incandescent sources. The Architect and Engineer must work together in the design phase to balance the effects of the new lighting code to produce the most effective and efficient HVAC system.

Incandescent lights are among the least efficient, but provide the most flattering light to skin tones. The aesthetically affects created by using non-traditional lighting, in an effort to reduce energy consumption, will require experimentation over the next couple of years until a happy balance of illumination, aesthetics, heat gain and energy consumption can be achieved.

The mechanical engineer will no longer be able to take the "per square foot" lighting factor for granted. The additionally fenestration, illumination controls, and lighting types required by EPACT '92, can and will alter the climate control needs during the day.

The cost of the lighting fixture to the mechanical climate control system represents one aspect of the total lighting cost. Analysis of the total lighting system is essential including, illumination, energy consumption, heat gain, building affects, and the relative cost of the lighting itself. The relative cost of lighting includes the cost of the fixture/bulb, installation, and energy consumption.
The table in figure A.3 **(6)** reflects the relative life-cycle cost of the most widely used lamps:

Table (1) RELATIVE COST OF BULBS



The change in the operating voltage for any of the above stated lamps will alter the efficiency, output, and life expectancy of the bulbs. A general rule of thumb is that for every one percent (1%) increase in voltage produces approximately a three percent (3%) increase in light output and a ten percent (10%) decrease in lamp life. All disciplines involved should have a basic understanding of how lights can and will affect the final design and mutually agree on the desired outcome.

Reducing the heat gain created by lighting is wonderful in the cooling months, but can offset the benefits those same lighting watts offer in the heating months. The benefits are more pronounced in a hot and humid climate due to the reduction in the required heating days. One watt of lighting produces approximately 3.4 Btu (1 W) of heat gain to a building space. Utilizing a larger air conditioning system, 1 kilowatt (1,000 W) of electricity is required for one ton (3.4 kW) of cooling. Therefore, every watt used for lighting in an air-conditioned space requires a minimum of 0.28 W of energy to cool the space. This fact is illustrated by the following equation:

$$(1 \text{ Watt}) \times (3.4 \text{ Btu/Watt}) \times (\text{ton-hour}/12{,}000 \text{ Btu}) \times (1000 \text{ Watt/ton}) = 0.28 \text{ Watt}$$

Equation (1)

Simply reducing one watt per square foot of lighting energy will result in 1.28 W/ft^2 of energy savings.

The energy savings realized in reducing the lighting wattage is a gross savings at best, heat gain through the additional fenestration or the demand for additional lights must be calculated into the final net energy savings (7).

Surface Finishes

Exterior colors of walls and roofs significantly affects the total amount of heat that is allowed to penetrate the interior of the building. Both the Architect and Engineer will benefit from selecting materials that reflect sunlight off the building. Dark colors absorb a greater amount of sunlight than lighter colors, therefore in a hot climate white colored or reflective (metallic) surfaces should be utilized.

The pitch of the roof will not have as much impact on the reflectance as the color, and therefore would not need to be initially considered.

Landscaping

Site development and layout in hot and humid climates, requiring maximum ventilation, can take advantage of the wind as a natural cooling element. Utilizing the wind is not limited to opening up a window, this would only pull hot and humid air in to the structure. The objective is to use the wind and landscaping to ultimately cool down the structure. Integration of the structure and the landscaping can result in channeling cooling breezes to "blow away" unwanted heat and moisture.

Strategically located windbreaks adjacent to a building can be used to manipulate the direction of airflow around and through a building. The wind convects heat away from both roof and wall surfaces of a building, and can also be used throughout the building for natural ventilation. Understanding the advantages and limitations of controlled landscaping, such as which seasons benefit the most of from wind manipulation, or deciduous plants, will enable the architect and engineer to maximize the affects.

Constricting and accelerating the natural prevailing wind flows in the vicinity of the building, provides natural ventilation demanded in humid areas, shading to reduce solar heat gain, and adds to the aesthetics of the building and site. Manipulation of the wind is best achieved with windbreaks. Windbreaks, correctly designed and located, utilize the environment by funneling in summer breezes and blocking winter winds. Prevailing winds originating from different directions simplifies the site layout. Hot humid climates typically enjoy the benefits of the winds from different directions, and should place ventilation openings and fenestration in the direction of the prevailing summer winds.

Conclusion

Engitectural Design is a common sense method for building design. The complex building systems encountered today require a deeper and better understanding of the building as a whole. Incorporating all the disciplines in the initial design phase does not and will not diminish the Architects role as the "building designer," but in fact reflects the willingness on behalf of the Architect to totally integrate the individual aspects of the building to create a functional, efficient work of art.

The design phase should begin with two lists, the owner's needs and the owner's wants. The agreed upon list will create a starting point from which all disciplines can begin an intelligent conversation regarding the most efficient avenue to reaching those goals. After weighting the pros and cons of each design element, from site orientation to landscaping, with input from all disciplines, the initial schematic design can be coordinated for visual and verbal presentation to the owner.

Engitectural Design seeks to give the building design professionals the edge when negotiating with the building owner. The owner will then be faced with the long term effects of the building design. It is much easier to persuade the owner to spend the money on landscaping if the Mechanical engineer can illustrate the pay back resulting from the cost savings to the HVAC system and energy budget, verses the whimsical desire of an Architect. Additionally, the mechanical engineer's desire to "over engineer" the system for self protection can be reduced by the better understanding of the total building design.

Hot and humid climates provide an excellent avenue for implementation of Engitectural Design, due to the fact that a vast number of mother natures characteristics and traits exist as solutions. The cooperation on behalf of the Architect and Engineer can reduce the energy cost, improve the efficiency of the system, as well as maintain the building as a work of art.

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